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Adaptation, mitigation and food security: Multi-criteria ranking system for climate-smart agriculture technologies illustrated for rainfed rice in Laos

R. Wassmann[a,b,*], J. Villanueva[c], M. Khounthavong[d], B.O. Okumu[d], T.B.T. Vo[a,e], B.O. Sander[f]

[a] International Rice Research Institute, Los Baños, Philippines
[b] Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Garmisch-Partenkirchen, Germany
[c] Currently at International Rice Research Institute, Lao Country Office, Vientiane, Lao People's Democratic Republic
[d] Cuso International, Laos Country Program, Vientiane, Lao People's Democratic Republic
[e] Cuu Long Delta Rice Research Institute, Can Tho, Viet Nam
[f] International Rice Research Institute, Vietnam Country Office, Hanoi, Viet Nam

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ABSTRACT

Climate-smart Agriculture (CSA) represents a commonly accepted term in referring to intended changes in agriculture production addressing climate change. Although specific definitions may vary, CSA is typically conceived as having three pillars, namely Adaptation, Food Security and Mitigation. These three pillars as such, however, do not suffice for assessing scaling potentials of different CSA technologies as several other drivers may accelerate or impede large-scale adoption. This paper introduces a systematic approach for a comparative assessment of technology-specific scaling potentials distinguishing among three clusters of criteria.

The ranking system requires scoring of CSA technologies by different stakeholder groups, namely farmers and extension workers/policy makers as well as research-based scoring. These scored values are then incorporated into a formula for calculating technology-specific ranking indices. This procedure also includes weighting factors to account for high and low significance of individual criteria for CSA scaling.

The entire scoring procedure is illustrated through the case of a Climate-smart Village in Laos which is dominated by rainfed rice with low resource inputs. Improvements of rice varieties and seed systems clearly emerged as the most promising CSA intervention. Ideally, seeds used by farmers should (i) be a drought-tolerant rice variety and (ii) have better quality in terms of seed vigor and purity. Finally, the article discusses the applicability and versatility of this ranking system for other land use systems.

- Core Criteria corresponding to the three pillars that are imperative for CSA scaling.
- Performance Criteria encompassing immediate ('on-farm') drivers of technology adoption.
- Leverage Criteria encompassing indirect ('off-farm') drivers of technology adoption.

1. Introduction

The term Climate-smart Agriculture (CSA) has become increasingly popular in various publications discussing the interface of climate change and small-holder farming (Lipper et al., 2014; Steenwerth et al., 2014; Rosenstock et al., 2016). According to FAO (2010), CSA is defined as "*agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals*". By this definition, CSA consists of three pillars, namely.

(i) adaptation – by building resilience to climate change and extremes
(ii) food security – by sustainably increasing agricultural productivity and incomes
(iii) mitigation – by reducing greenhouse gas emissions and/or increasing carbon sequestration

FAO in 2017 further specified that CSA is "*an approach for developing actions needed to transform and reorient agricultural systems to effectively* support *development and ensure food security under climate change*". In a nutshell, CSA differs from 'business-as-usual' approaches by promoting coordinated actions by farmers, researchers, private sector, civil society and policymakers as a means to increase the adaptive capacity of

* Corresponding author. International Rice Research Institute, Los Baños, Philippines.
E-mail address: r.wassmann@irri.org (R. Wassmann).

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farmers as well as to increase resilience and resource use efficiency in agricultural production systems (Lipper et al., 2014; Steenwerth et al., 2014). In terms of the three pillars, adaptation and food security have generally been considered as obvious goals for agriculture development under climate change (Rosenstock et al., 2016). In contrast, CSA mitigation targets have received some critical comments questioning its rationale for smallholder farmers which led to more elaborate discussions on the role of mitigation within a broader CSA approach (Harvey et al., 2013).

Moreover, it is understood that CSA cannot be implemented through blanket strategies, but will require identifying agricultural technologies suitable to local conditions (Taneja et al., 2014; Kakraliya et al., 2018). CSA is often fused with other agricultural approaches such as sustainable intensification (Campbell et al., 2014) and conservation agriculture (Kaczan et al., 2013). In the case of rice production, CSA principles have been integrated into the production standard propagated by the Sustainable Rice Platform (Ellis et al., 2014). In recent years, CSA has often been conceived within a landscape approach (Scherr et al., 2012). Collectively, interventions in the land use systems should result in ‘climate-smart landscapes’.

In spite of broad discussions of the scientific basis of CSA (Rosenstock et al., 2016; Shirsath et al., 2017), there is considerable uncertainty with regard to quantification of CSA impacts. Only mitigation has a commonly accepted metrics to quantify impacts, namely carbon dioxide equivalents (CO_2e), that can be translated into definite development targets (Wollenberg et al., 2016). As for food security, different indicators can be applied to assess potential food availability at household level (Lopez-Ridaura et al., 2018). For adaptation, however, the means of quantification are unclear. Yield gains over time may be taken as a proxy, but it is not clear how to translate those into quantifiable benefits of CSA vis-à-vis secular trends stemming from infrastructure development or technological innovations in agriculture (Rejesus et al., 2014).

By the same token, yield changes alone will be insufficient for impact assessments as CSA objectives encompass many facets of social resilience beyond yield performance. Moreover, the scaling potential of CSA technologies[1] will not only depend on these pillars, but also on several other factors that may accelerate or impede large-scale adoption. Thus, this paper introduces a systematic approach for a comparative assessment of technology-specific CSA scaling potentials.

The objectives of this paper are:

1. Reviewing the manifold criteria that have previously been mentioned as relevant for CSA scaling and structure them into a plausible and comprehensible framework
2. Developing a transparent ranking system for different CSA technologies in rice-dominated landscapes within a site-specific or regional context
3. Devising a protocol for scoring[2] of technologies by different stakeholder groups as the basis of computing a technology-specific Ranking Index and apply this to a Climate-smart Village (CSV)
4. Assessing the CSV results in view of applying this ranking system for other land use systems

2. Rationale for a new ranking system

The rationale for developing a multi-criteria ranking system derives from a literature review that revealed a multitude of different studies dealing with CSA assessments in one way or the other. Table 1 gives an overview on the diverse contexts and purposes of CSA ranking that have been published over recent years. For all studies listed in Table 1, the CSA technology assessment is typically seen as the initial step of CSA scaling. The ensuing scaling builds on both top-down approaches (e.g. catalyzing new policies) as well as bottom-up approaches (e.g. building evidence). This listing of 15 contexts and purposes also reflects a large variation in scales targeted by different CSA assessments which will be discussed in more detail below (Chapter 6).

The dissemination of CSA technologies forms the backbone of the CGIAR Research Program ‘Climate Change, Agriculture and Food Security’ (CCAFS). CCAFS has developed a conceptual framework for different CSA components as shown in Fig. 1. This framework can be obtained in slightly-modified versions from different CCAFS sources, but in all cases the technologies are grouped according to the principle improvement targeted by the CSA technology without further classification criteria.

While this CCAFS framework represents an initial overview of the possible technologies, this type of characterization has clear limitations. Many CSA technologies will fall under several of the given columns, e.g. Alternate Wetting and Drying (AWD) in rice production can be classified as weather-smart, water-smart and carbon-smart. Moreover, this classification lacks any form of prioritization needed under the ubiquitous limitation of resources that can be devoted to CSA scaling.

Effectively all publications on CSA concur that there is a need to go beyond the three CSA pillars for assessing the suitability of a given technology for scaling of CSA, but other criteria are given rather arbitrarily derived from individual observations or empirical evidence from case studies. Several approaches for assessing CSA technologies have been developed that are either based on field data, farmer/stakeholder surveys or a combination of both. In case of the cropping systems of Northern India, CSA technologies have been ranked based on yield performance (Kakraliya et al., 2018) and economic returns (Jat et al., 2018). Other approaches derive a ranking of CSA technologies from participatory tools. For instance, the climate smart agriculture rapid appraisal assesses the spatial heterogeneity (through qualitative and quantitative attributes) and prioritizes context-specific CSA options (Mwongera et al., 2017).

At this point, however, a clearly defined multi-criteria assessment approach for CSA is missing. Given the complexity and heterogeneity of agriculture production systems, this lack of structure and hierarchy among scaling criteria impairs a proper synthesis of CSA technologies. In turn, there is clear need to incorporate diverse factors that may either accelerate or impeded adoption. The following features should be embedded in the new framework:

- building upon expertise from different stakeholders (farmers, extension workers, policy makers, researchers) derived from their specific competence in assessing different aspects of CSA;
- considering different scales (household and village) and exploring technology assessments up to country scale;
- weighting among highly-important vs. less-important assessment criteria
- providing evidence on the applicability through a test of the method.

3. Case study: climate-smart village dominated by rainfed rice in Laos

The multi-criteria CSA ranking system presented in this publication has evolved out of a CCAFS project on Climate-smart Villages (CSV) in the Mekong Basin conducted by the International Rice Research

[1] The term ‘technology’ is used in this study in a broad sense encompassing simple changes in agricultural practices as well as high-tech innovations.

[2] In the context of this newly developed methodology, the term ‘ranking’ is used for the overall inter-comparison of CSA technologies while ‘scoring’ refers to the individual assessments as described in the procedure below; thus, scoring values are defined by farmers and extension workers/policy makers as well as a research-based assessment whereas the Ranking Index is calculated based on those scoring values.

Table 1
Compilation of different purposes and contexts for CSA technology assessment derived from literature review.

Purpose/context of CSA Ranking	Reference
Assessment of global mitigation and adaptation potentials by CSA	Challinor et al., 2014, Powlson et al., 2014, Rosenstock et al., 2016, Steenwerth et al., 2014, Wassmann and Pathak, 2007, Wollenberg et al., 2016
Defining new policies through scenario-guided impact assessments	Vervoort et al., 2014, Westermann et al., 2018
Contributing to Nationally Appropriate Mitigation Action (NAMA) and Nationally Determined Contribution (NDC)	Kibria et al., 2018, Mwongera et al., 2017, Sapkota et al., 2019, Westermann et al., 2018
Prioritizing investment strategies in development programs	Long et al., 2016, FAO, 2010, Westermann et al., 2018
Documenting reduced risks to food security from climate change	Campbell et al., 2016, Lipper et al., 2014, Lopez-Ridaura et al., 2018
Building evidence on specific benefits for promoting the CSA concept	Aggarwal et al., 2018, Brandt et al., 2015, Jat et al., 2016, Jat et al., 2018, Kakraliya et al., 2018, Mwongera et al., 2017, Scherr et al., 2012, Taneja et al., 2014, Totin et al., 2018
Better design and inter-comparison of individual CSA technologies	Aggarwal et al., 2018, Khatri-Chhetri et al., 2017, Mwongera et al., 2017, Sapkota et al., 2019, Shirsath et al., 2017, Westermann et al., 2018, Zougmore et al., 2018
Assessing suitability to identify 'best-bet' CSA technologies across scales	Sander et al., 2017, Shirsath et al., 2017
Identifying technology-specific factors for acceleration and hurdles for adoption	Aryal et al., 2018, Brandt et al., 2015, Harvey et al., 2013
Mainstreaming through capacity building for key public, private and civil society actors	Brandt et al., 2015, Harvey et al., 2013, Kaczan et al., 2013, Rejesus et al., 2014, Westermann et al., 2018, Wright et al., 2014
Developing business cases for private sector involvement	Long et al., 2016, Westermann et al., 2018
Developing pathways out of poverty	Hellin and Fisher, 2018, Zougmore et al., 2018
Reducing gender gap through CSA scaling	Huyer, 2016, Jost et al., 2016, Nelson and Huyer, 2016
Defining sustainability indicators under the CSA concept	Campbell et al., 2014, Ellis et al., 2014, Gowing and Palmer, 2007
Prioritizing research needs	Harvey et al., 2013, Rosenstock et al., 2016, Taylor, 2018, Totin et al., 2018

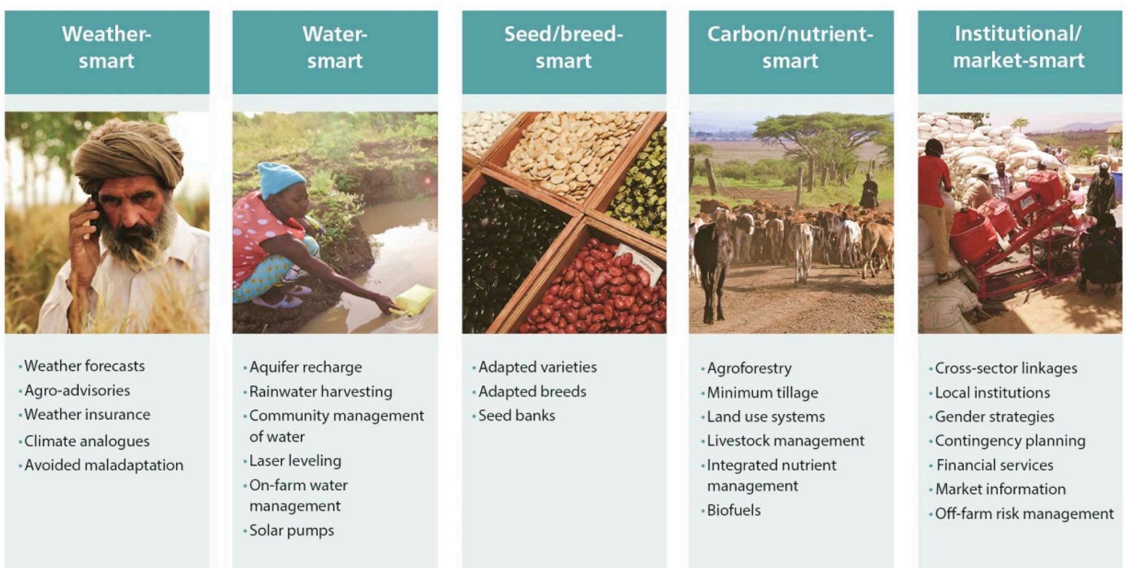

Fig. 1. CCAFS approach to characterize CSA technologies within a CSV (adopted from Aggarwal et al., 2018).

Institute and partner organizations. In Phailom (Savannakhet Province, Lao PDR), almost the entire rice paddy is rainfed rice while only 4% of the land has irrigation (Villanueva et al., 2015). Inputs are generally low; fertilizers are absent or given at low doses. At the village setting, the demographic data of the survey clearly reflected male out-migration (mainly for working in Thailand), so that the number of women is 60% higher than men being present in the village.

This village can be taken as typical case for rice-dominated landscapes in the central Mekong Basin with a dominance of rainfed systems. In the case of Lao PDR, rainfed lowland rice area accounts for 65% of the total rice area and 69% of the production (Schiller et al., 2001). In South Laos where this CSV is located, rainfall variability exerts major production constraints. Especially at the onset of the rainy season, insufficient rainfall presents an aggravating problem, so that the wet season rice crop cannot be transplanted in time for achieving high yields in unfavorable years (Lacombe et al., 2012).

This study was part of a program by CCAFS that has established CSVs in different parts of the world. The overall objective of this program is to develop a range of CSA interventions in close collaboration with local farmers and a range of different partners. The research questions address the practical steps that smallholder farmers can take to adjust their agricultural technologies as well as the catalytic effects needed for scaling from one village to a larger geographic area.

As for all CSVs under the CCAFS program, the establishment of the CSV Phailom has started with a household baseline survey (Villanueva et al., 2015). The baseline survey encompassed about 150 households in this CSV as well as nearby villages. After 4-years of operation, the CSV project now moves from an initial phase that focused on individual CSA interventions to a more holistic approach cutting across various scales.

As part of this transition, the project team has compiled a coherent list of technologies that can further be used for broader CSA scaling activities. Field evidence alone, however, cannot be taken as sole argument in favor or against successful CSA implementation. For instance mitigation is one of the pillars of CSA, but will obviously not appear in any need assessment conducted with farming communities. Thus, it was unclear on how to proceed with this criterion in assessing the prospects

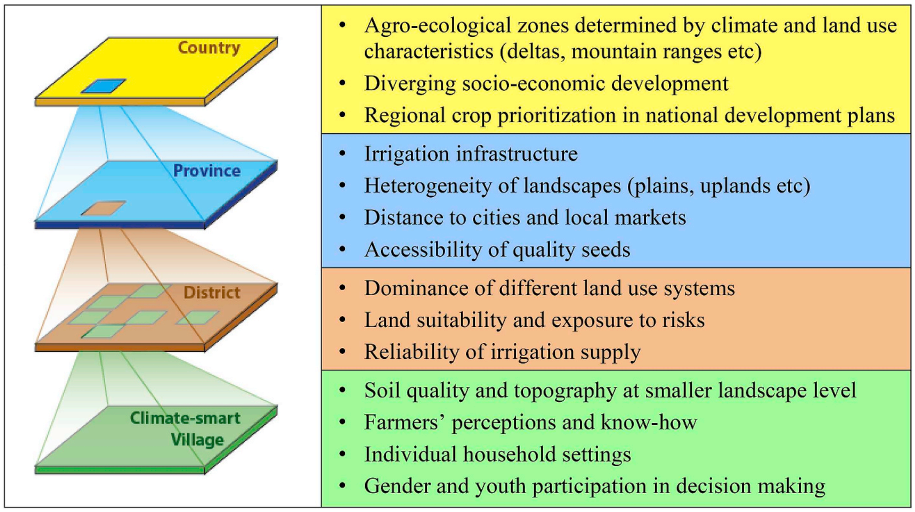

Fig. 2. Schematic presentation of scale-dependent sources of internal variation.

of CSA scaling. Our working hypothesis is that CSA technologies can only be assessed through consideration of different stakeholder groups as well as research-based assessments covering the entirety of CSA criteria.

4. New ranking system for CSA technologies

The new ranking system distinguishes among three clusters containing three criteria each for assessing the scaling potential of a given technology by incorporating perspectives from different stakeholders as well as empirical evidence from research (Table 2). The first cluster comprises the three pillars of CSA that are denoted as 'Core Criteria' in this ranking system. While the underlying ideas behind *Adaptation Potential* (C1), *Food Security Benefits* (C2) and *Mitigation Potential* (C3) have been described in more detail above, it seems obvious that these defining criteria of CSA have to play a major role in ranking of CSA scaling potential. The second cluster ('Performance Criteria') reflects observations derived from 'on-farm' performances of CSA technologies. Those encompass *Farmer Incentives* (P1) denoting both, the profitability as well as the possible obstacles in implementing a given technology. While profitability is an inherent – and obvious – prerequisite of adoption (Kakraliya et al., 2018; Sapkota et al., 2019), scaling of a technology that is deemed profitable can be severely constrained by either exogenous (e.g. limited access to technology) or endogenous (e.g. required behavioral changes) factors (Wassmann and Pathak, 2007; Beuchelt and Badstue, 2013; Khatri-Chhetri et al., 2017). The second Performance Criterion *Opportunities for Scaling* (P2) allows the scoring of 'low-hanging fruits' for scaling, i.e. technologies that will only need some catalytic support for large-scale adoption. This also corresponds to the concept of targeted CSA intervention that prioritizes the most promising options at national scale (Steenwerth et al., 2014; Brandt et al., 2015). *Maturity of Technology* (P3) assesses the proof of concept of a given technology based on evidence in previous implementations that could range from pilot scale to dissemination over larger areas. This can be assessed through meta-analysis of various CSA technologies (Rosenstock et al., 2016) as well as through identifying suitability of CSA technologies for different environments (Powlson et al., 2014; Jansson et al., 2018).

The third cluster is composed of 'Leverage Criteria' (Table 2). None of those three criteria will be sufficient to accomplish technology adoption in its own right, but they could accelerate broader adoption due to support coming from different sources. *Community and Gender Benefits* (L1) could become an asset from the perspective of local stakeholders to stimulate technology adoption (Wright et al., 2014; Jost et al., 2016; Nelson and Huyer, 2016; Huyer, 2016). *Policy Backing* (L2) is important to remove administrative hurdles and actively promote technology adoption (Lipper et al., 2014; Taylor, 2018). The criterion *Paradigm Shift Potential* (L3) recognizes the significance of genuinely innovative approaches as opposed technologies that follow the business-as-usual track. This aspect has been highlighted right from the onset of conceptualizing climate-smart agriculture (Gowing and Palmer, 2007). While the term 'Paradigm Shift Potential' may not be clearly defined in the literature, one cannot ignore its relevance in CSA proposals aiming at external funding. Several funding agencies (including the Green Climate Fund) require convincing evidence of paradigm shifts that can be accomplished through CSA technologies.

Moreover, the multi-criteria ranking system also considers specific competences by distinct stakeholder groups. The assessment of *Adaptation Potential (C1)*, *Farmer Incentives (P1)* and *Community/Gender Benefits (L1)* is seen as the prerogative of the farmers as those criteria can best be assessed at household level. On the other hand, extension workers and policy makers appear the most qualified group to assess *Food Security Benefits (C2), Opportunities for Scaling (P2)* and *Policy Alignment (L2)*. Those criteria will require a broader perspective

Table 2
Overview of clusters and criteria for assessing CSA scaling potential.

Clusters	Core Criteria	Performance Criteria	Leverage Criteria
Description of criteria within cluster	Representing the CSA pillars and imperative for any CSA scaling	Encompassing immediate ('on-farm') drivers of technology adoption	Encompassing indirect ('off-farm') drivers of technology adoption
Criteria scored by farmers	*C1) Adaptation Potential*	*P1) Farmer Incentives*	*L1) Commun./Gender Benefits*
Criteria scored by extension workers/ policy makers	*C2) Food Security Benefits*	*P2) Opportunities for Scaling*	*L2) Policy Alignment*
Criteria for research-based scoring	*C3) Mitigation Potential*	*P3) Maturity of Technology*	*L3) Paradigm Shift Potential*
Weighting Factor	3	2	1

considering different sources of variation across scales (Fig. 2). *Mitigation Potential (C3), Maturity of Technology (P3)* and *Paradigm Shift Potential (L3)* will require a more generic assessment derived from reviewing available data published in reports and literature.

Finally, the ranking system also weights individual criteria clusters regarding their significance against each other for a quantitative assessment in form of a scaling index. As shown in Table 2, we have assigned weighting factors to provide more emphasis on the ranking of Core Criteria (weighting factor = 3) as compared to Performance Criteria (weighting factor = 2) and Leverage Criteria (weighting factor = 1). The justification of emphasizing Core Criteria is given by their imperative character for CSA scaling. Technologies that rank low for these criteria will have very limited value in terms CSA scaling. Performance Criteria receive an intermediate weighting factor of 2 which recognizes the immediate impact of technology performance on its scalability. Leverage Criteria represent beneficial drivers for CSA scaling, but eventually those will become irrelevant as long as a technology is scored low in both Core Criteria and Performance Criteria.

The Ranking Index comprises a numerical presentation of the CSA scaling potential of a given technology. As the required scoring procedure has to be done for a specific location or target region, the procedure for calculating the Ranking Index is explained below alongside with the case study on the CSV.

5. Scoring procedures illustrated for the CSV case

The scoring procedure of CSA technologies comprises four steps as illustrated for the CSV in South Laos.

5.1. STEP 1: defining a set of possible CSA technologies

In the course of the 4-year project, a set of 11 technologies have been identified as potential candidates for CSA scaling that are shown with their short names in Figs. 3–5 and with full names in Table 3. Those potential CSA technologies exclude changes in water management such as AWD that are seen as very promising in irrigated rice but are impractical in rainfed systems. Moreover, farmers in this CSV use only – if any – low amounts of fertilizers, so that optimization strategies for nitrogen applications are also absent from this list.

5.2. STEP 2: scoring of technologies according to clearly defined questions

As explained above, the scoring of a given criterion will be done either by farmers (*C1, P1, L1*), extension workers/policy makers (*C2, P2, L2*) or through research-based assessment (*C3, P3, L3*). As this article aims at illustrating the methodology, we refrain here from showing the details of the stakeholder interviews and the research-based scoring that will both be described in a future publication. In case of the farmers, all interviewees were familiar with the CSA technologies from previous project activities while the scoring of CSA technologies was done in Focus Group discussions using one scoring card for each technology.

The questions addressing farmers and extension workers/policy makers are shown in Figs. 3 and 4, respectively, while the guiding questions for the research-based scoring are shown in Fig. 5. For each question/criterion, one technology can be scored with a maximum value of 5 and minimum of 1. The best-performing technology automatically receives a score of 5 and the least-performing technology a score of 1, so that the entire scoring scale will be used for each question/criterion to ensure scoring over the full range of values.

5.3. STEP 3: quantification of technology-specific ranking indices

These individual scoring values are then used to calculate a Ranking Index per technology based on the generic equation:

$$RI_{Tn} = \sum (Sc_{Tn} \text{ x } WF_{Tn}) / \max \sum (Sc_{Tn} \text{ x } WF_{Tn})$$

In which:

RI_{Tn} = Ranking Index of a technology [in %]
Sc_{Tn} = Score of a given technology (as shown in Figs. 3–5 for the CSV)
WF_{Tn} = Weighting Factor of respective technology (according to cluster)

The maximum scoring sum that can be achieved through optimum values for each cluster is 15, so that the maximum value for all nine criteria is 90 in this case.

$$RI_{Tn} = \sum (Sc_{Tn} \text{ x } WF_{Tn}) / 15 \text{ x } (3 + 2 + 1) = \sum (Sc_{Tn} \text{ x } WF_{Tn})/90$$

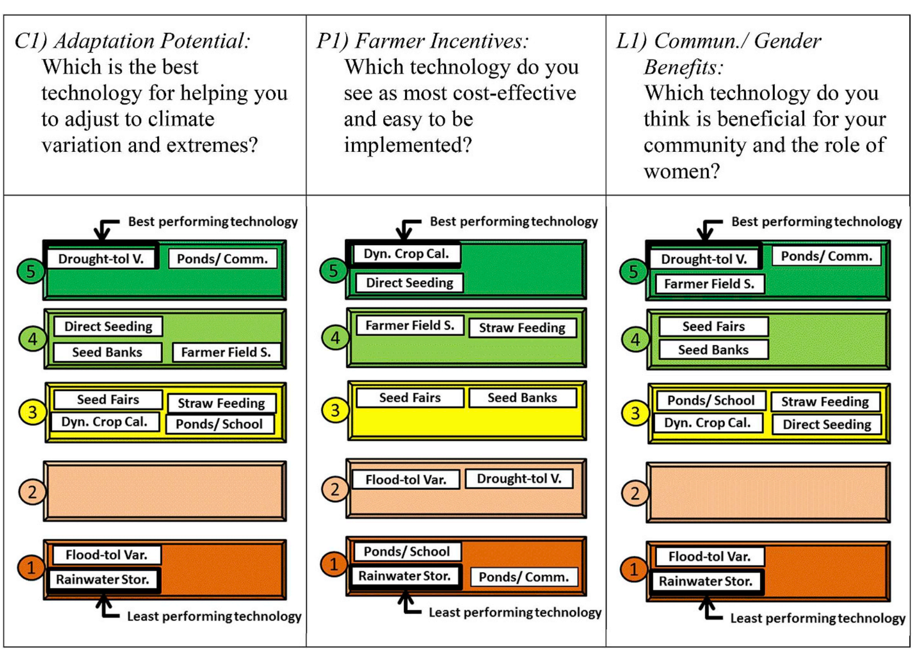

Fig. 3. Scoring questions for farmers in CSV case study.

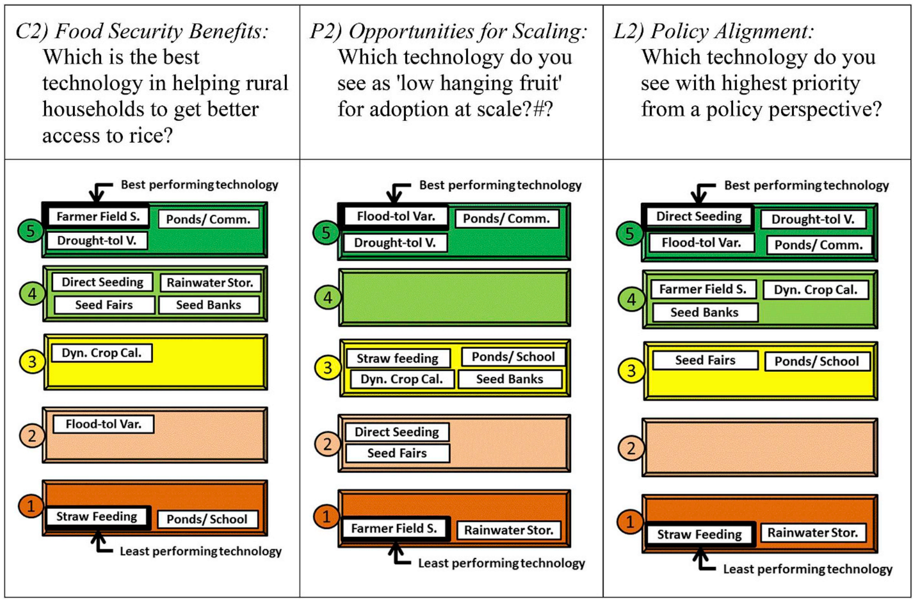

Fig. 4. Scoring questions for extension workers/policy makers in CSV case study.

5.4. STEP 4: interpretation of computed results

This procedure has led to the values for technology-specific Ranking Indices shown in Table 3. These values allow inter-comparison of technologies based on scaling potential. In contrast to highly managed irrigated systems, rainfed rice offers a constrained portfolio of suitable CSA technologies which has already been reflected in the limited number of options in Figs. 3–5. In those irrigated systems, changes in water management, namely Alternate Wetting and Drying, have been identified as very efficient CSA technology fostering both adaptation and mitigation. By the nature of rainfed systems, water management can hardly be changed. Water storage through ponds and rainwater collection may suffice for garden-scale vegetable production (Jacq et al., 2018), but not for rice during the dry season.

6. Scale-dependent variations and boundaries

As schematically shown in Fig. 2, technology ranking inherently has to cope with variations within any conceivable scale from village to country, but the sources of internal variations differ across scales. At the lowest level of this hierarchy, namely village scale, internal variations can appropriately be assessed through the agronomic studies and survey-based approaches as described above.

But even though a specific village might be deemed as ‘typical’ for the entire district, individual villages within the district will differ from each other by the share of different land use systems and other sources of variation. Ranking of CSA technologies at district level could integrate these variations by considering different villages in a given district as shown in Fig. 2. In principle, the same approach could be applied to province level (consisting of several districts) as well as country level (consisting of several provinces), but it seems unrealistic to achieve this level of distinction within one project from village to country scale. In turn, the sources of variation at province and country scale have to be used for specifying system boundaries of the CSA ranking. At province scale, the ranking will only be applicable to land use systems with similar irrigation infrastructure, landscape structure,

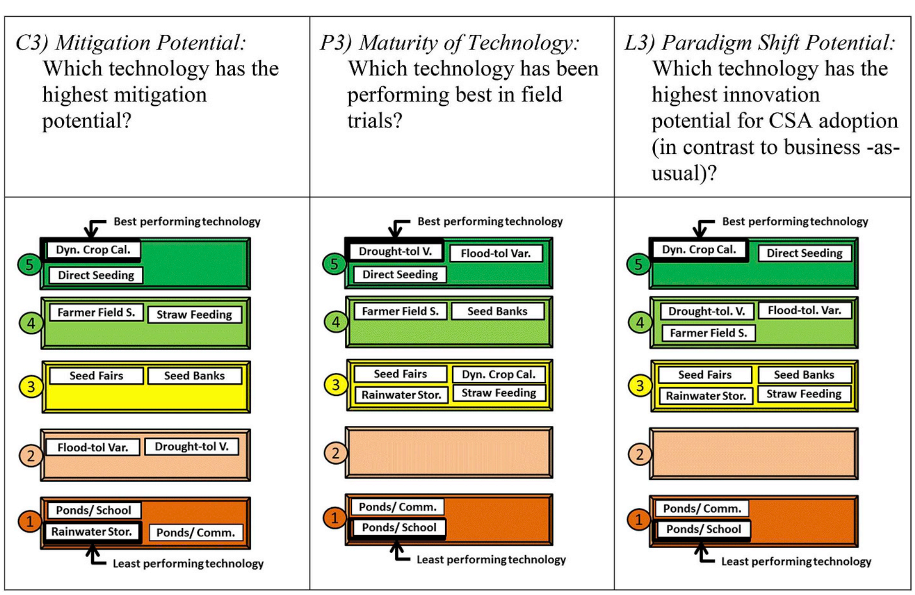

Fig. 5. Scoring questions for research-based assessments in CSV case study.

Table 3
Technology-specific ranking indices for CSV case study.

CSA Technology	Sum of weighted scores[a]	Ranking Index[b]
Drought-tolerant rice varieties disseminated	80	89%
Direct seeding disseminated	74	82%
Ponds for community gardens	66	73%
Farmer field schools conducted	70	78%
Seed banks operated by the community	64	71%
Dynamic crop calendar applied	63	70%
Seed fairs conducted	55	61%
Straw feeding to cattle	49	54%
Flood-tolerant rice varieties disseminated	47	52%
Pond for school garden	38	42%
Rainwater storage tank for vegetable production	33	37%

[a] $\Sigma(Sc_{Tn} * WF_{Tn})$.
[b] $\Sigma(Sc_{Tn} * WF_{Tn})/90$.

distance to cities and accessibility of seeds. At national scale, the validity of the CSA assessment can be narrowed down to one province and neighboring provinces with high degree of similarity.

It is understood though, that the hierarchy of scale-dependent variations shown in Fig. 2 is only schematic and may differ depending on the respective case study and country. In fact, even the administrative terminology may differ, e.g. some countries have municipalities, but no districts. Moreover, the causes of variation may in some cases also be discernible at other scales than the one shown in Fig. 2, but this should not deter from the principle concept of their scale-dependence. Finally, it should be noted that this concept of sclae-dependent variation has been developed for crop production systems, so that the causes of variations may differ for other food systems, e.g. animal husbandry. Nevertheless, any conceivable food system will have a pronounced sources of of scale-dependent variations that have to be considered for CSA scaling .

7. Conclusion

The specific relevance of this study derives from presenting a new method to assess CSA technologies. While CSA scaling has been described previously (e.g. Lipper et al., 2014; Steenwerth et al., 2014; Rosenstock et al., 2016; Harvey et al., 2013), the criteria for technology assessment have not yet been structured in a systematic fashion to disentangle the underlying mechanisms for a favorable or unfavorable impact on technology scaling.

Given the existing vulnerabilities to climate change, the rainfed rice systems discussed in this article represent apt targets for climate-smart interventions (Wassmann et al., 2009). Yield levels are generally low which can be attributed to lack of irrigation infrastructure and market access in combination with pronounced climate variability. Under these conditions, farmers will rely on low-cost options to increase the adaptive capacity of their land use system. Four of the top five interventions identified in this study are related to rice varieties and seed supply. In practical terms, CSA interventions should start with introducing improved rice varieties that can better cope with adverse climatic conditions, namely droughts. In the next step, those seeds should be multiplied in standardized protocols resulting in seed material that has high vigor and negligible contamination of weeds. Meeting those quality standards can either be accomplished in government-operated seed multiplication centers or – supported by training – through community-based systems. Only one option in the list of top five refers to another intervention, namely establishing ponds for community-based vegetable gardens. This can be seen as a 'low-hanging fruit' in environments like in this CSV, although land property rights can become a major obstacle for operating ponds for community purposes.

In our case study, we have surveyed farmers who have already been familiar with CSA technologies. For some farmers, this familiarity was attributed to first-hand experience in applying the respective technology. However, we have also included farmers ('non-adopters') who have acquired awareness on the pros and cons of CSA technologies derived from training and observations without practicing all of them on their own farm. Thus, the selection of farmers with familiarity of the CSA technogies should not represent an inherent bias in this technology assessment. Obviously, not all farmers will embrace the innovations coming along with CSA, but even the non-adopters may also provide valuable technology scorings.

Although we have not tested this new ranking system beyond this CSV, the overall concept of ranking CSA interventions comprises generic features that should also be applicable to other CSA projects. The structuring of criteria into clusters, inclusion of different stakeholder groups in the ranking process as well as assigning weighting factors to different criteria could potentially be incorporated into other CSA assessment as well. That being said, the ranking system also embeds a certain degree of subjectivity derived from the specific experiences in the CSV project. On the other hand, this concern will inherently apply to any ranking system for assessing CSA potentials.

In our study, we have applied the ranking system at village scale and we have also discussed the boundaries of our approach. While this ranking system can in principle be applied to national scale, this will require a large amount of farmer interviews to cope with the inherent variations at the lower scales. In spite of these considerations, we are confident that this study and the new ranking system will help to stimulate further discussions on CSA scaling as well as possible avenues to achieve far-reaching success in this endeavor.

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